US009205897B2

(12) **United States Patent**
Wang et al.

(10) **Patent No.: US 9,205,897 B2**
(45) **Date of Patent: Dec. 8, 2015**

(54) **C-SEMI WITH MINIMUM HYDRODYNAMIC FORCES**

(75) Inventors: **Tao Wang**, Katy, TX (US); **Yijian Zeng**, Katy, TX (US)

(73) Assignee: **AKER SOLUTIONS INC.**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 171 days.

(21) Appl. No.: **13/988,714**

(22) PCT Filed: **Nov. 22, 2011**

(86) PCT No.: **PCT/US2011/061834**

§ 371 (c)(1), (2), (4) Date: **Aug. 13, 2013**

(87) PCT Pub. No.: **WO2012/071407**

PCT Pub. Date: **May 31, 2012**

(65) **Prior Publication Data**

US 2013/0319314 A1 Dec. 5, 2013

Related U.S. Application Data

(60) Provisional application No. 61/416,570, filed on Nov. 23, 2010.

(51) **Int. Cl.**

B63B 35/44 (2006.01)
B63B 1/10 (2006.01)

(52) **U.S. Cl.**

CPC ***B63B 35/4413*** (2013.01); ***B63B 1/107*** (2013.01)

(58) **Field of Classification Search**

USPC 114/264–266
IPC B63B 35/4413,35/44, 1/107
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,717,113	A *	2/1973	Wilde	114/264
2004/0040487	A1*	3/2004	Kristensen et al.	114/265
2005/0058513	A1*	3/2005	Martensson et al.	405/203
2006/0067793	A1*	3/2006	Murray	405/205
2012/0111256	A1*	5/2012	Xu	114/265

* cited by examiner

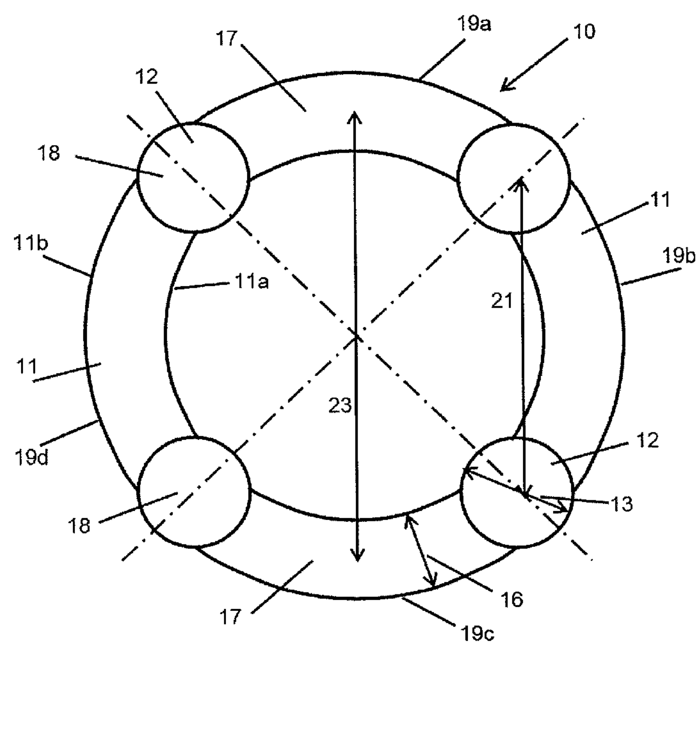
Primary Examiner — Stephen Avila

(74) *Attorney, Agent, or Firm* — Rothwell, Figg, Ernst & Manbeck, P.C.

(57) **ABSTRACT**

An offshore floating structure (**10**) for the drilling and production of oil and gas includes a generally circular toroidal, hollow pontoon (**11**) of substantially the same radial width throughout a perimeter of the pontoon. The offshore floating structure includes a plurality of columns (**12**) of substantially a same cross-sectional area, each coupled at a coupling point, on a bottom end thereof to the pontoon at an equidistant point along the perimeter of the pontoon, and adapted to be coupled on a top end to a deck structure. The diameter (**23**) from a center of the radial width of the pontoon is greater than a distance (**21**) from a center of one column to a center of an adjacent column.

10 Claims, 15 Drawing Sheets



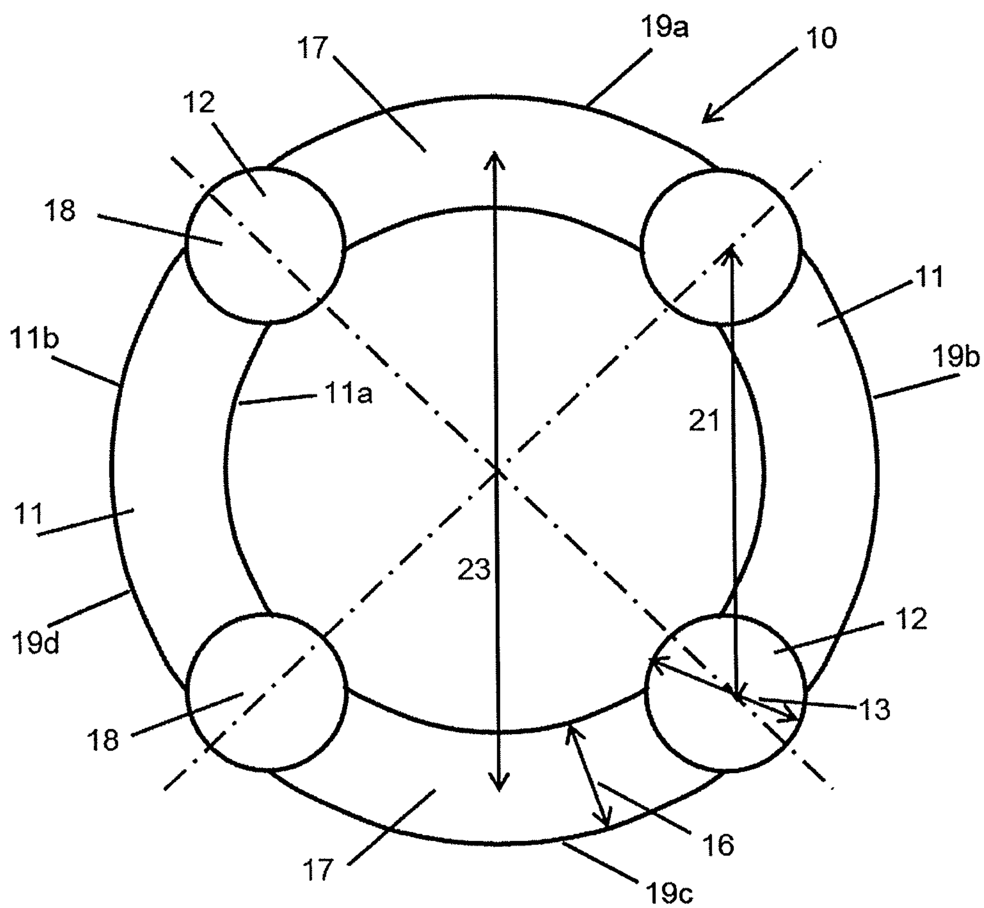


FIG. 1

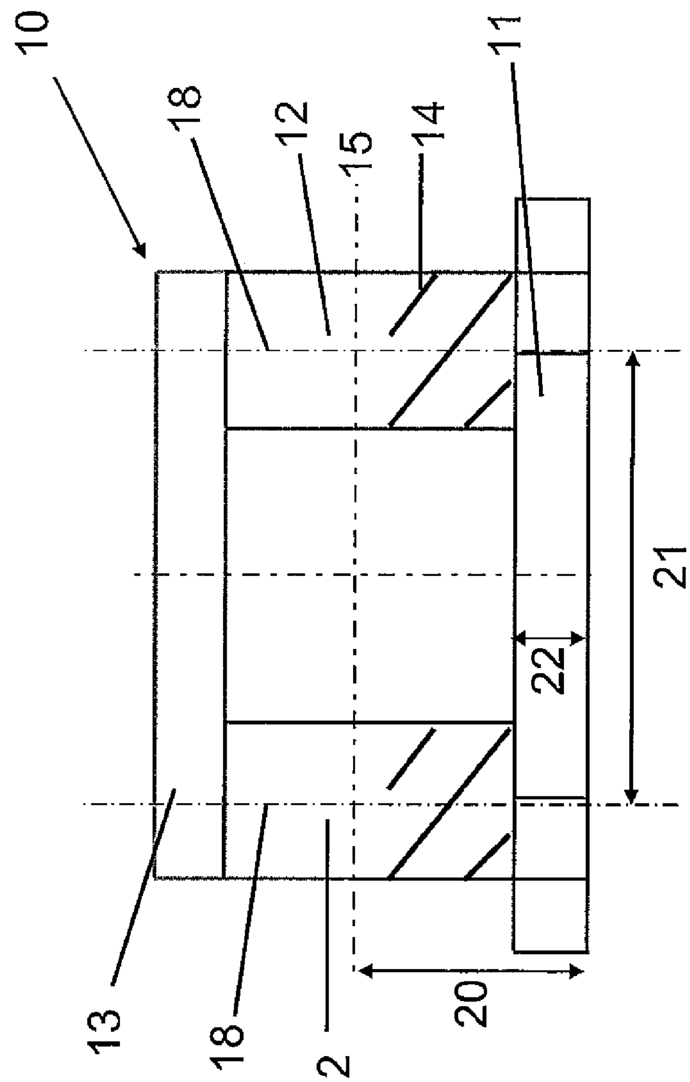


FIG. 2

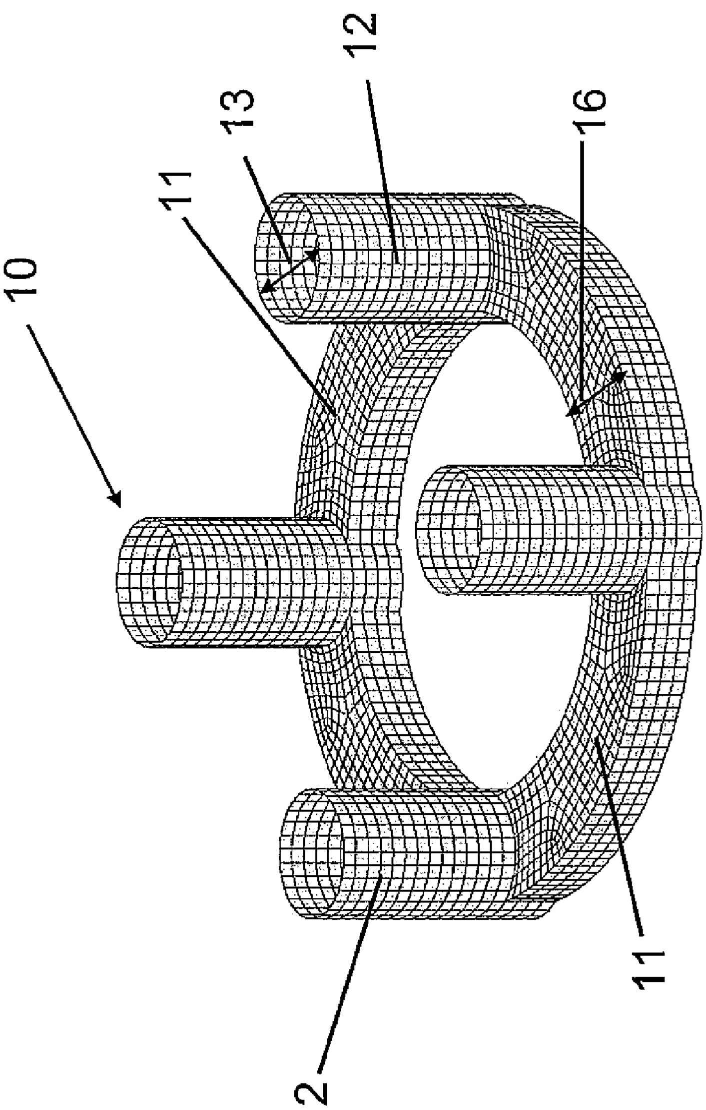


FIG. 3

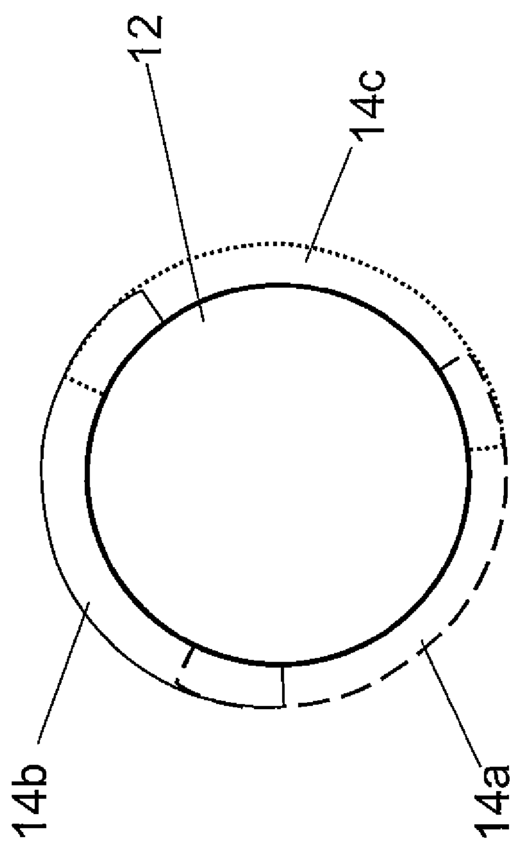


FIG. 4

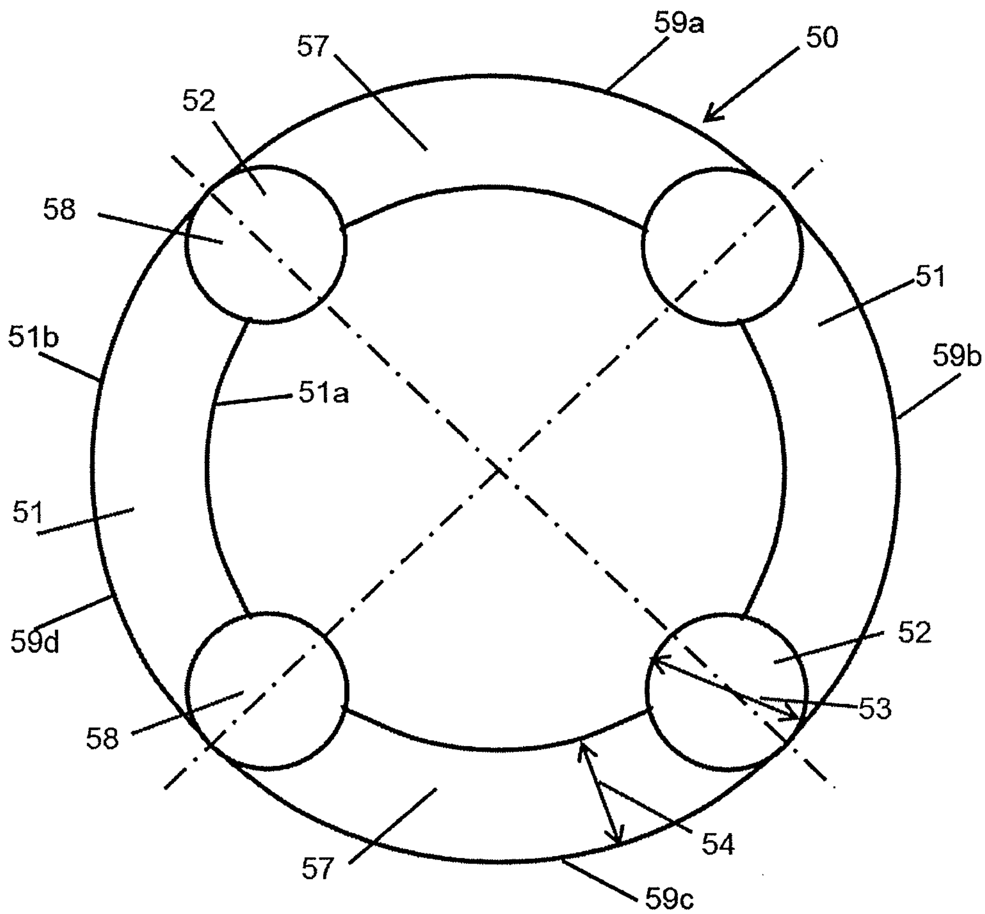


FIG. 5

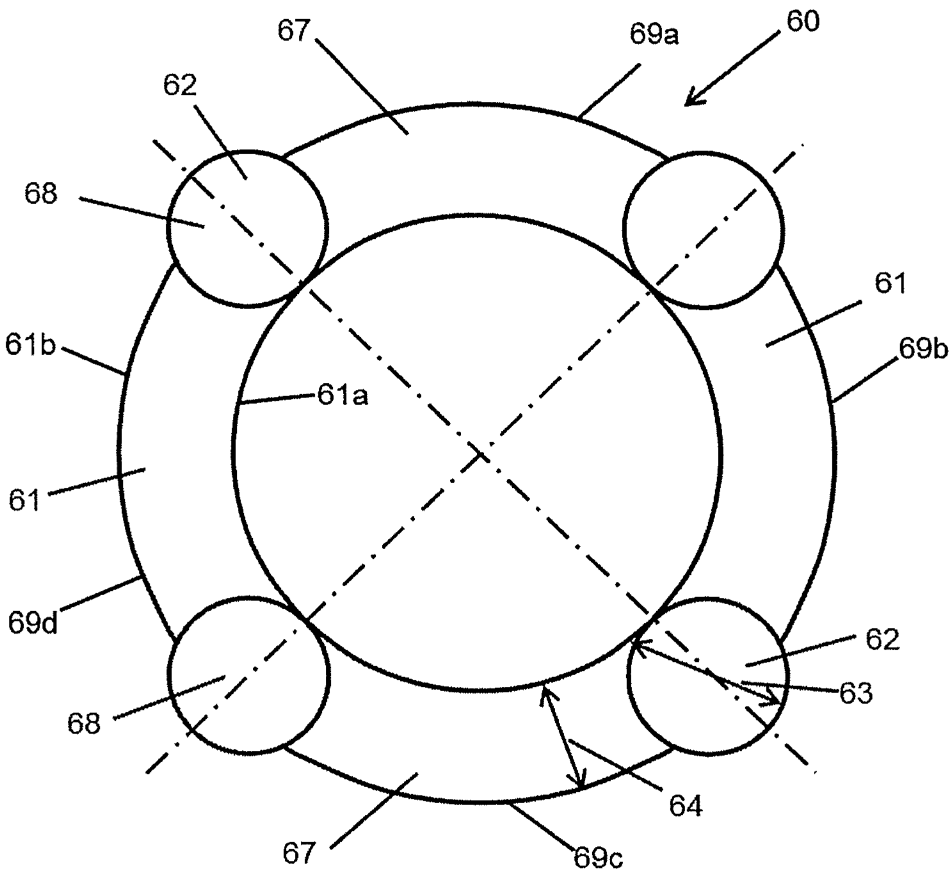


FIG. 6

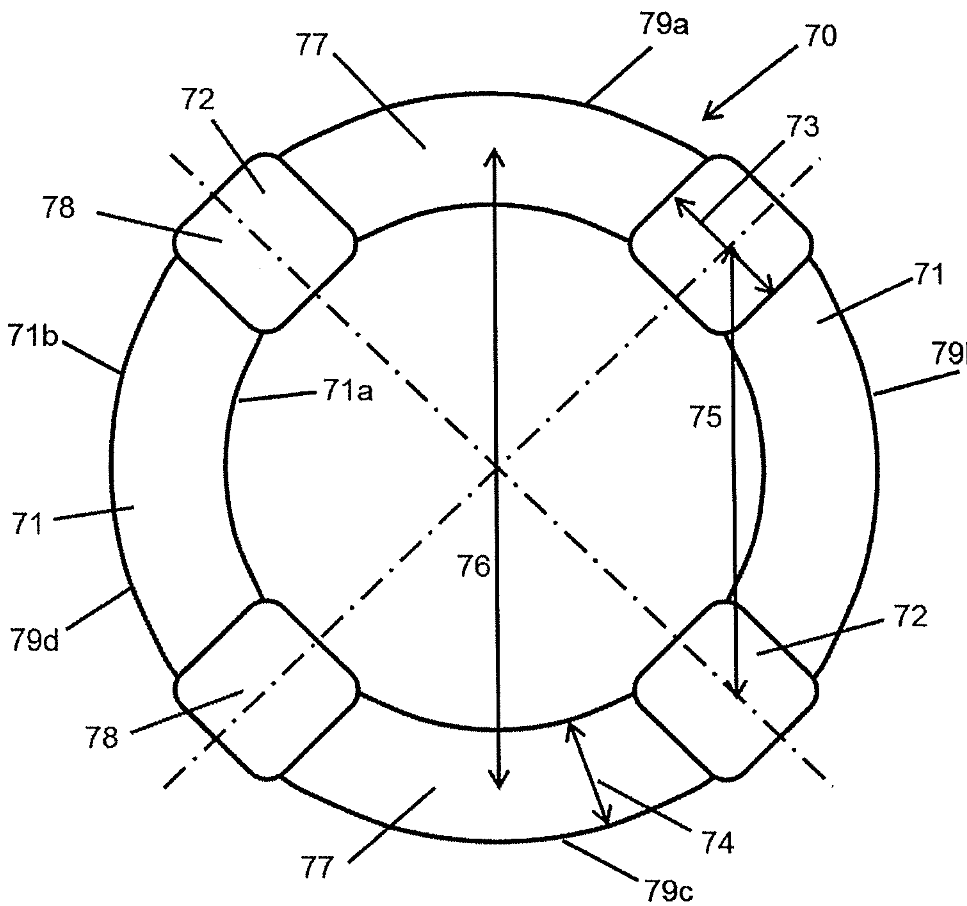


FIG. 7

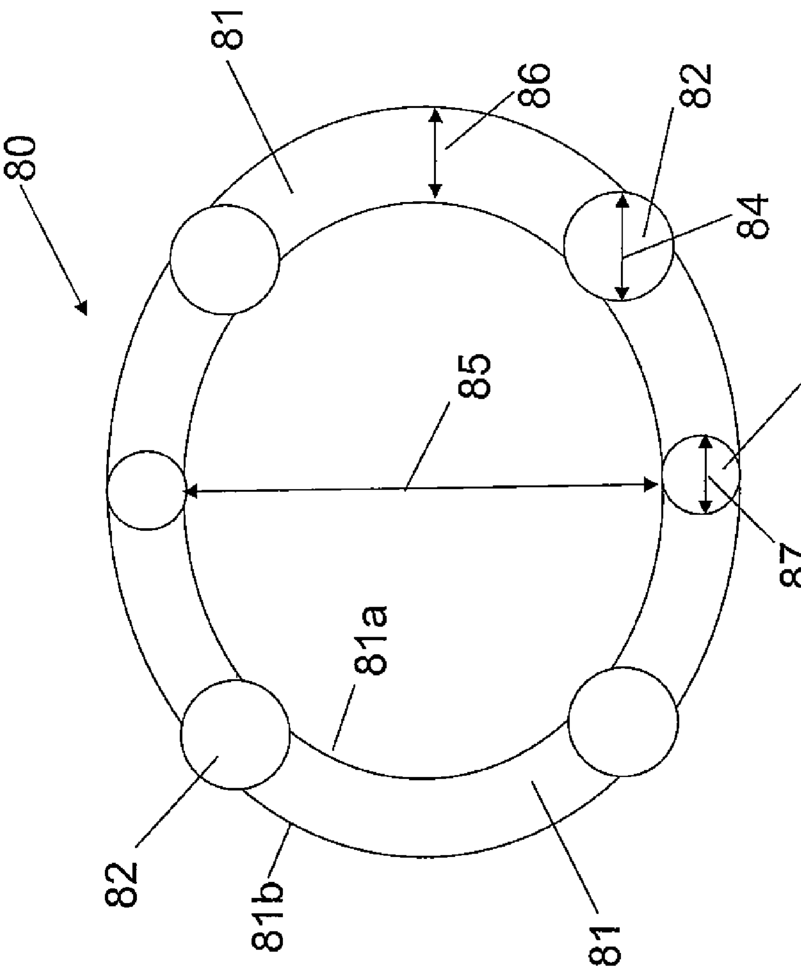


FIG. 8

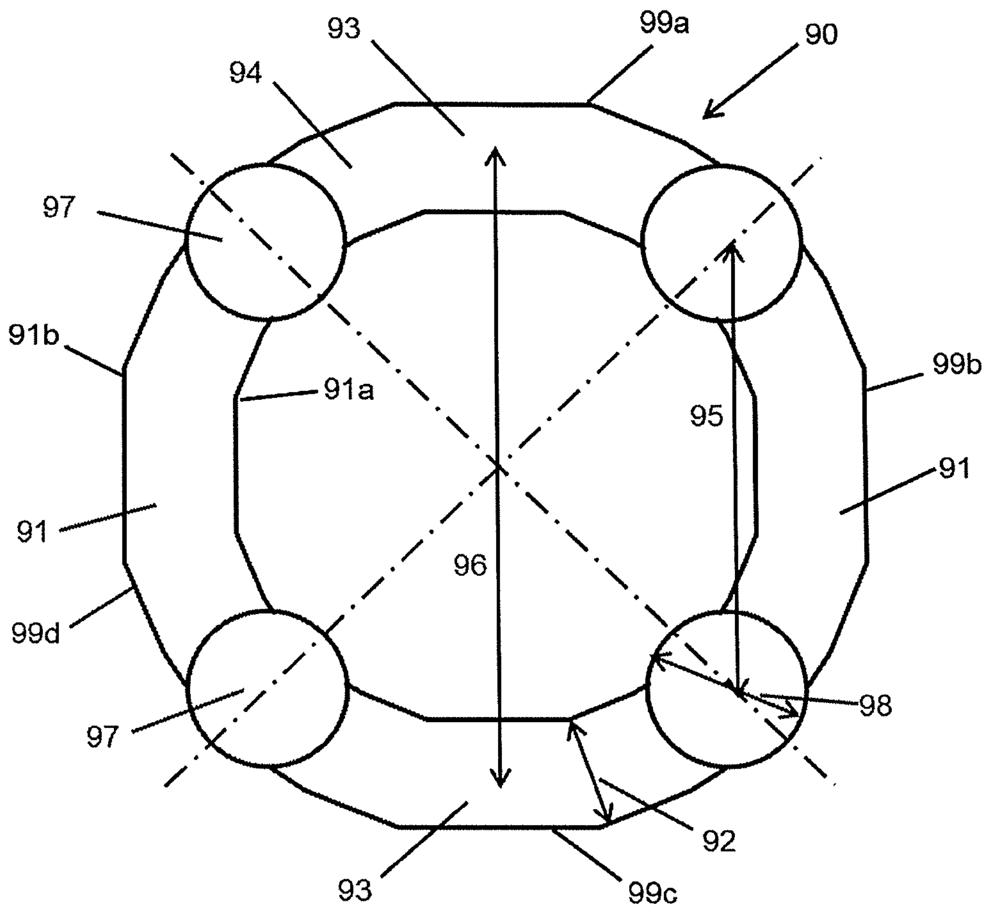


FIG. 9

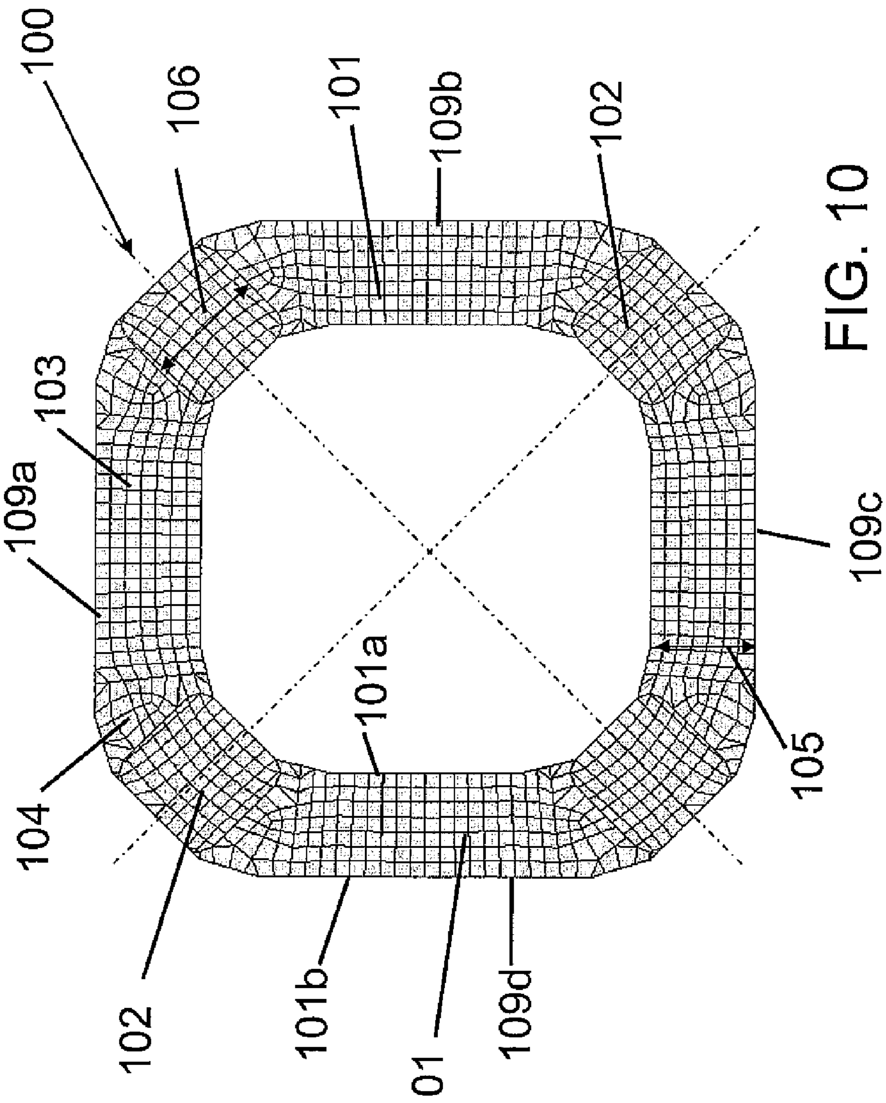

100
106
101
109b
102
103
109a
109c
101a
105
104
102
101b
101
109d

FIG. 10

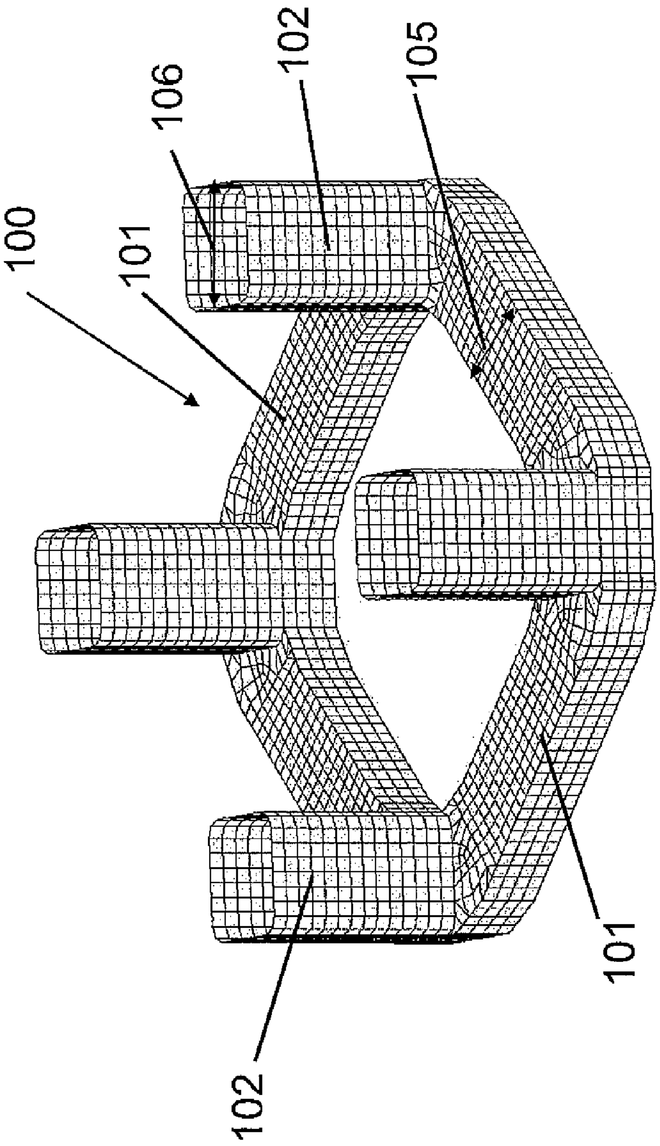


FIG. 11

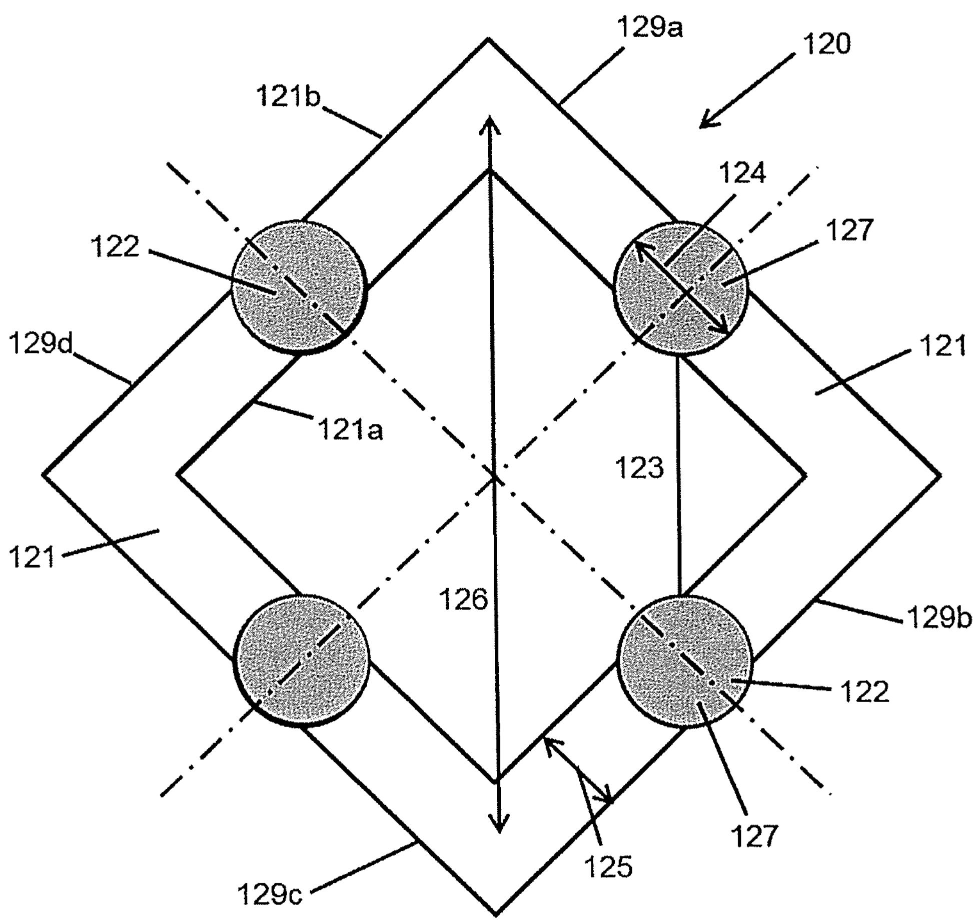

129a
120
121b
124
122
127
129d
121
121a
123
121
126
129b
122
127
125
129c

FIG. 12

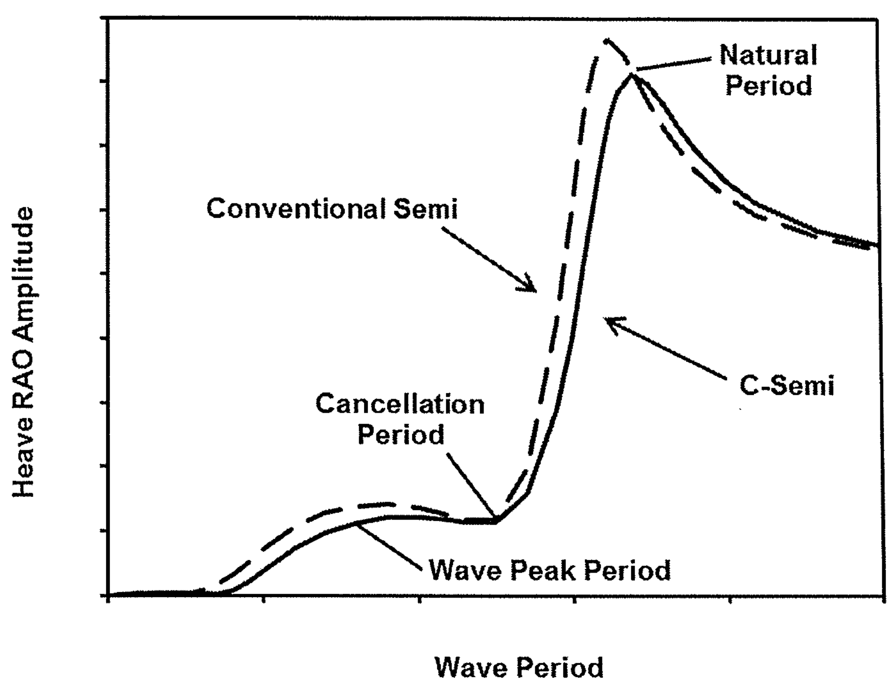

Natural
Period
Conventional Semi
C-Semi
Cancellation
Period
Wave Peak Period
Heave RAO Amplitude
Wave Period

FIG. 13

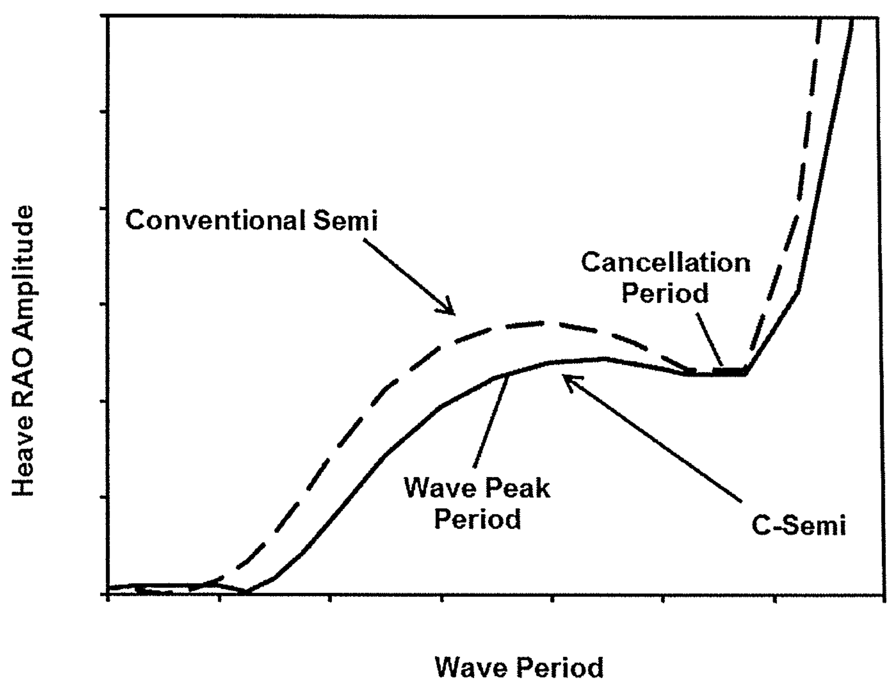

Heave RAO Amplitude
Conventional Semi
Cancellation
Period
Wave Peak
Period
C-Semi
Wave Period

FIG. 14

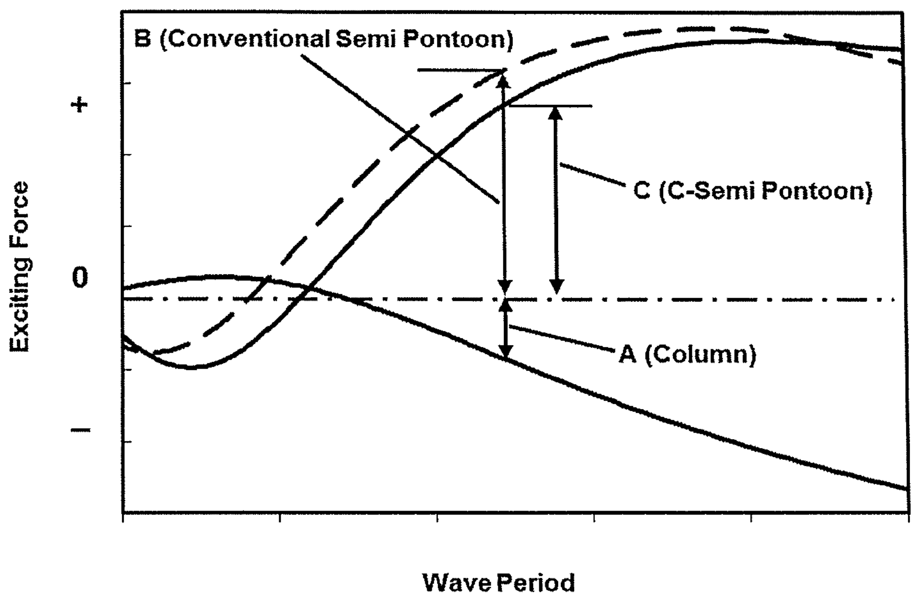

B (Conventional Semi Pontoon)
+
C (C-Semi Pontoon)
Exciting Force
0
A (Column)
–
Wave Period

FIG. 15

C-SEMI WITH MINIMUM HYDRODYNAMIC FORCES

CLAIM OF PRIORITY OR CROSS-REFERENCE TO RELATED APPLICATION

This application is a 35 U.S.C. §371 National Phase Entry Application from PCT/US2011/061834, filed Nov. 22, 2011, and designating the U.S., which claims the benefit of priority to Provisional Patent Application Ser. No. 61/416,570, filed Nov. 23, 2010, the contents of which are incorporated herein by reference in their entirety.

FIELD OF THE INVENTION

The present invention relates generally to an offshore floating platform for the drilling and production of oil and gas. Specifically, the invention relates to a circular cylindrical semi-submersible platform (C-Semi) for offshore drilling and production.

BACKGROUND OF THE INVENTION

Floating structures used for offshore oil and gas drilling and production are known. One such floating structure is conventional semi-submersible hulls. A conventional semi-submersible hull has a square pontoon structure. The square pontoon structure is coupled to four square shaped columns placed at the four corners of the pontoon structure. Therefore, the pontoon section length is the same as the length separating the columns.

In a conventional semi-submersible hull, the columns do not have strakes. Each column is connected to a deck structure to support topside facilities. A spread mooring or dynamic positioning system is used for station keeping.

Conventional semi-submersible hulls have several limitations. They are subject to large heave, roll and pitch motions. A conventional semi-submersible hull is unable to support steel catenary risers in extreme weather conditions. These steel catenary risers also have fatigue problems in long term operating conditions. Furthermore, a conventional semi-submersible hull is unable to be used for dry tree production applications while undergoing these motions.

There are also known variants of this structure that alter the draft and the column distance of the floating platform. In traditional structures, the length of the pontoon structure is considerably larger than the draft. In an attempt to reduce the effects of motions experienced in extreme and operating weather conditions, structures were developed with an increased draft and/or modified column distance. However, these deep draft variants are still operationally limited.

Another type of known floating structure is an extendable draft platform (EDP). An EDP structure includes a buoyant equipment deck. The buoyant equipment deck is either rectangular or triangular. Column wells are coupled to each corner of the buoyant equipment. On an opposite end, the columns are coupled to a heave plate. In an EDP structure, each of the columns has an upper portion with a diameter that is different from that of a lower portion, which is usually smaller. The columns can move vertically in the column well to adjust the draft.

EDP structures have several limitations. EDP structures are difficult to manufacture and maintain because they use complex, large moving components. Additionally, strong subsurface currents can cause vortex-induced vibrations (VIV).

A structure that has prolonged exposure to VIV can experience fatigue damage to components and is subject to structural failure.

A dual column semi-submersible hull is a known floating structure as well. A dual column semi-submersible hull has a deck structure that is supported by vertical columns arranged in pairs. In these structures, one set of the paired columns is displaced a distance outward from the other set of paired columns. The other set of paired columns is in line with a pontoon structure. The lower ends of this set of vertical columns are connected to the pontoon structures.

The dual column semi-submersible hull, at a much deeper draft, has better performance than a conventional semi-submersible hull at a much shallower draft. However, at the same draft, the dual column semi-submersible hull only marginally improves the motions of a conventional semi-submersible hull. In addition, the dual columns complicate design, fabrication and operation.

There is also a central pontoon semi-submersible floating platform. The central pontoon structure is disposed inboard of the columns, with each of said vertical support columns having a transverse cross sectional shape with a horizontal major axis oriented radially outward from a center point of said hull. However, the vertical wave force on the central pontoon not substantially cancelled by the forces on the columns. This arrangement has adverse effects, and can result in worse vertical motions than a conventional semi-submersible hull at the same draft.

The other known semi-submersible is octabuoy. The draft of octabuoy is substantially greater than the distance between the columns' central axes. The columns have quite large diameter relative to the length of pontoon section, and the pontoon section length is around 2 times column diameter. As a result, the column displacement is a few times greater than the pontoon displacement, and the wave forces on the columns will make a greater contribution than the force on the pontoon. The most preferred draft of octabuoy is at least 60 meters, and the most preferred ratio of draft to the distance between central axes of columns is 1.3 to 1.35. The substantially deep draft required makes it cannot integrate topsides at quaysides because of water depth limitations. Additionally, float over operations near the shore are required. The nonlinear shape and variant cross section of columns also increases fabrication complexity.

Therefore, for the drilling and production of offshore oil and gas, there is a need for a simple floating structure that is subject to minimized environmental forces and platform motions compared with known semi-submersibles.

SUMMARY OF THE INVENTION

According to an embodiment of the present invention, a C-Semi floating platform for offshore production and drilling includes a generally circular toroidal, hollow pontoon, a plurality of columns, a deck structure, and topside facilities. The circular cylindrical pontoon can be comprised of straight and curved sections. The diameter from a center of the radial width of the pontoon is larger than the distance from one column center to an adjacent column center. At the intersection points of columns and pontoon, the cross-sectional area of columns is generally greater than, but can be equal to or less than, the corresponding area of pontoon. The columns have a cross section that is either circular or square with rounded corners. If desired, each column can be provided with overlapping helical strakes, which extend across the entirety of the column perimeter below the waterline.

In one embodiment of the present invention, the offshore floating structure for the drilling and production of oil and gas includes a generally circular toroidal, hollow pontoon of substantially the same radial width throughout a perimeter of the pontoon. The offshore floating structure includes a plurality of columns of substantially a same cross-sectional area, each coupled at a coupling point, on a bottom end thereof to the pontoon at an equidistant point along the perimeter of the pontoon, and adapted to be coupled on a top end to a deck structure. The diameter from a center of the radial width of the pontoon is greater than a distance from a center of one column to a center of an adjacent column.

According to another embodiment of the present invention, the offshore floating structure is a hollow, oval toroidal pontoon of substantially a same radial width throughout the perimeter of the pontoon. The offshore floating structure includes four large columns of substantially a same cross-sectional area, each coupled on a bottom end thereof to the pontoon at an equidistant point along the perimeter of the pontoon forming two non-shortest diameters. Each large column is also adapted to be coupled on a top end to a deck structure. The offshore drilling structure also includes two small columns of substantially a same cross-sectional area, each coupled on a bottom end thereof to the pontoon at an equidistant point along the perimeter of the pontoon forming the shortest diameter. Each small column is also adapted to be coupled on a top end to a deck structure.

According to another embodiment of the present invention, the offshore floating structure is a hollow, rectangular cuboid pontoon of substantially a same radial width throughout a perimeter of the pontoon. The offshore floating structure includes four columns of substantially a same cross-sectional area, each coupled on a bottom end thereof to the pontoon at the center of each side of the pontoon. Each column is also adapted to be coupled on a top end to a deck structure.

The present invention offers utility for semi-submersible drilling and production units including wet trees with steel catenary risers (SCR) and/or dry trees with top tensioned risers (TTR). Additionally, the C-Semi hull is applicable for Tension Leg Platforms (TLPs).

The C-Semi offers several advantages, including minimized wave, current and vortex induced motions, and structural forces. These advantages significantly improve hull, mooring and riser system performance. Additionally, the present invention reduces the costs and risks typically in offshore oil and gas field development.

Further features and advantages of the present invention shall be understood in view of the following description with reference to the drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

While the present invention may be embodied in many different forms, a number of illustrative embodiments are described herein with reference to the accompanying figures. The skilled person should understand that the present disclosure is to be considered as providing examples of the principles of the invention, and such examples are not intended to limit the invention to the preferred embodiment described herein and/or illustrated herein.

FIG. **1** is a plan view of a C-Semi, according to an embodiment of the present invention.

FIG. **2** is an elevation view of a C-Semi, according to an embodiment of the present invention.

FIG. **3** is a perspective view of a C-semi, according to an embodiment of the present invention.

FIG. **4** is a detailed view of an individual column with strakes, according to another embodiment of the present invention.

FIG. **5** is a plan view of a C-Semi with the pontoon offset to the outside, according to another embodiment of the present invention.

FIG. **6** is a plan view of a C-Semi with the pontoon offset to the inside, according to another embodiment of the present invention.

FIG. **7** is a plan view of a C-Semi with square columns, according to another embodiment of the present invention.

FIG. **8** is a plan view of a C-Semi with six columns, according to another embodiment of the present invention.

FIG. **9** is a plan view of a C-Semi with straight pontoon middle sections and circular columns, according to another embodiment of the present invention.

FIG. **10** is a plan view of a C-Semi with straight pontoon middle sections and square columns, according to another embodiment of the present invention.

FIG. **11** is a perspective view of a C-Semi with straight pontoon middle sections and square columns, according to another embodiment of the present invention.

FIG. **12** is a plan view of a C-Semi with a square pontoon and circular columns, according to another embodiment of the present invention.

FIG. **13** is a graph displaying the heave response amplitude operators (RAO) for a C-Semi (as embodied in FIG. **3**) and conventional semi-submersible hull both at the same draft.

FIG. **14** is a graph displaying the heave response amplitude operators (RAO) around wave peak period for a C-Semi (as embodied in FIG. **3**) and conventional semi-submersible hull both at the same draft.

FIG. **15** is a graph displaying the wave exciting forces on the pontoon and columns in the vertical direction for a C-Semi (as embodied in FIG. **3**) and a conventional semi-submersible hull both at the same draft.

DETAILED DESCRIPTION OF THE INVENTION

FIG. **1** is a plan view of a C-semi **10** with a circular cylindrical pontoon **11** according to an embodiment of the present invention. As shown, the four circular cylindrical columns **12** are coupled to the pontoon **11** at points along the perimeter of the pontoon **11** equidistant from each other. While the pontoon **11** may be a single structure or several separate structures, for ease in description, the pontoon **11** will be referred to as having four sections or quadrants **19***a*, **19***b*, **19***c* and **19***d*; each section is coupled to and positioned between two adjacent columns **12**. The pontoon **11** is a circular, hollow toroid with an interior edge **11***a* and an exterior edge **11***b*. The pontoon can be filled with buoyant material such as air, or ballast such as water.

In this embodiment, parts of each column **12** can extend radially beyond the interior and exterior edges of the pontoon **11**. The maximum width (in this case the diameter) **13** of the columns **12** is larger than the radial width **16** of the pontoon **11**. Therefore, at the point where the column **12** intersects the pontoon **11**, the cross-sectional area of each column **12** is greater than the corresponding area of the pontoon **11**. The diameter from the center of the radial width of one pontoon section **17** to the center of the radial width of an opposite pontoon section **17** is larger than the distance from the center of one column **18** to the center of an adjacent column **18**. A spread mooring (not shown) can be used for station keeping of the C-Semi.

FIG. **2** is an elevation view of the C-Semi **10** with a circular cylindrical pontoon **11** according to this embodiment of the present invention. A deck structure **13** can be connected to the top end of columns **12**. Strakes **14** can be provided on the exterior of the columns **12** below the mean waterline **15** to mitigate vortex induced motions. The columns **12** can be attached to the pontoon **11** on the end opposite the deck structure **13**.

The pontoon sections are positioned radially outward relative to the columns. The diameter **23** from the center of the radial width of one pontoon section **17** to the center of the radial width of an opposite pontoon section **17** is preferably between 1.2 to 1.5 times the distance **21** from the center of one column **18** to the center of an adjacent column **18**. The pontoon sections are substantially longer relative to the column width **13**, and the distance **21** between central axes of adjacent columns is preferably 3.5 to 4 times the column width **13**. The preferred draft **20** is generally between 20 to 50 meters. The draft is between 0.3 and 1 times the distance **21** from the center of one column **18** to the center of an adjacent column **18**. The draft is also typically much less than the distance **21** between central axes of adjacent columns. The pontoon width **16** varies from 0.6 to 1 times the column width **13**. The preferred pontoon height **22** is in the range of 0.4 to 0.8 times the pontoon width **16**. The column displacement is between 0.8 to 2 times the pontoon displacement. The wave forces on the columns contribute less than the force on the pontoon for most wave periods.

FIG. **3** is a perspective view of the C-semi **10** with a circular cylindrical pontoon **11** according to this embodiment of the present invention. As shown, the four circular cylindrical columns **12** can be coupled to the pontoon **11** at equidistant points along the pontoon **11**.

FIG. **4** is a plan view of an individual column **12** according to another embodiment of the present invention. The exterior of each column can be provided with three overlapping helical strakes **14***a*, **14***b* and **14***c*, which fully cover the column **12** perimeter below the waterline.

FIG. **5** is a plan view of a C-Semi **50** with a circular cylindrical pontoon **51** according to another embodiment of the present invention. As shown, the four circular cylindrical columns **52** can be coupled to the pontoon **51** at points along the perimeter of the pontoon **51** equidistant from each other. The pontoon **51** is a is a circular, hollow toroid with an interior edge **51***a* and an exterior edge **51***b*.

While the pontoon **51** may be a single structure or several separate structures, for ease in description, the pontoon **51** will be referred to as having four sections or quadrants **59***a*, **59***b*, **59***c* and **59***d*; each section is coupled to two adjacent columns **58**. As shown, the maximum width (in this case the diameter) **53** of the columns **52** is larger than the radial width **54** of the pontoon **51**. Therefore, at the point where the column **52** intersects the pontoon **51**, the cross-sectional area of each column **52** is greater than the corresponding area of the pontoon **51**. In this embodiment, as shown, parts of each column **52** extend radially beyond only the interior edge **51***a* of the pontoon **51**. The edge of a column **52** can be in line with the outer circumferential edge of the pontoon **51**. The diameter from the center of the radial width of one pontoon section **57** to the center of the radial width of an opposite pontoon section **57** is larger than the distance from the center of one column **58** to the center of an adjacent column **58**.

FIG. **6** is a plan view of a C-Semi **60** with a circular cylindrical pontoon **61** according to another embodiment of the present invention. As shown, the four circular cylindrical columns **62** can be coupled to the pontoon **61** at points along the perimeter of the pontoon **61** equidistant from each other. The pontoon **61** is a circular, hollow toroid with an interior edge **61***a* and an exterior edge **61***b*.

While the pontoon **61** may be a single structure or several separate structures, for ease in description, the pontoon **61** will be referred to as having four sections or quadrants **69***a*, **69***b*, **69***c* and **69***d*; each section is coupled to two adjacent columns **68**. The maximum width (in this case the diameter) **63** of the columns **62** is larger than the radial width **64** of the pontoon **61**. Therefore, at the point where the column **62** intersects the pontoon **61**, the cross-sectional area of each column **62** is greater than the corresponding area of the pontoon **61**. In this embodiment, as shown, parts of each column **62** extend radially beyond only the exterior edge **61***b* of the pontoon **61**. The diameter from the center of the radial width of one pontoon section **67** to the center of the radial width of an opposite pontoon section **67** is larger than the distance from the center of one column **68** to the center of an adjacent column **68**.

FIG. **7** is a plan view of a C-Semi **70** with a circular cylindrical pontoon **71** according to another embodiment of the present invention. As shown, the four square cylindrical columns **72** with round corners can be coupled to the pontoon **71** at points along the perimeter of the pontoon **71** equidistant from each other. The pontoon **71** is a circular, hollow toroid with an interior edge **71***a* and an exterior edge **71***b*.

While the pontoon **71** may be a single structure or several separate structures, for ease in description, the pontoon **71** will be referred to as having four sections or quadrants **79***a*, **79***b*, **79***c* and **79***d*; each section is coupled to two adjacent columns **78**. The maximum width **73** of the columns **72** is larger than the radial width **74** of the pontoon **71**. Therefore, at the point where the column **72** intersects the pontoon **71**, the cross-sectional area of each column **72** is greater than the corresponding area of the pontoon **71**. In this embodiment, as shown, parts of each column **72** extend radially beyond only the exterior edge **71***b* of the pontoon **71**. The diameter from the center of the radial width of one pontoon section **77** to the center of the radial width of an opposite pontoon section **77** is larger than the distance from the center of one column **78** to the center of an adjacent column **78**.

The pontoon sections are positioned radially outward relative to the columns. The diameter **76** from the center of the radial width of one pontoon section **77** to the center of the radial width of an opposite pontoon section **77** is preferably between 1.2 to 1.5 times the distance **75** from the center of one column **78** to the center of an adjacent column **78**. The pontoon sections are substantially longer relative to the column width **73**, and the distance **75** between central axes of adjacent columns is preferably 3.5 to 4 times the column width **73**. The preferred draft is generally between 20 to 50 meters. The draft is between 0.3 and 1 times the distance **75** from the center of one column **18** to the center of an adjacent column **78**. The draft is also typically much less than the distance **75** between central axes of adjacent columns. The pontoon width **74** varies from 0.6 to 1 times the column width **73**. The preferred pontoon height is in the range of 0.4 to 0.8 times the pontoon width **74**. The column displacement is between 0.8 to 2 times the pontoon displacement. The wave forces on the columns contribute less than the force on the pontoon for most wave periods.

FIG. **8** is a plan view of a C-Semi **80** according to another embodiment of the present invention. The pontoon is an oval, hollow toroid with an interior edge **81***a* and an exterior edge **81***b*. As shown, two small cylindrical columns **83** can be coupled to the pontoon **81** such that the distance between the coupling points of the columns and the interior of the pontoon forms the shortest diameter **85** of the oval pontoon **81**. The two small cylindrical columns **83** can have a maximum width **87** that is equal to the radial distance **86** from the interior edge

81*a* to the exterior edge **81***b* of the pontoon **81**. The other four large columns **82** can be coupled to the oval pontoon **81** at opposite ends of two diameters that do not comprise the shortest diameter of the oval.

The four large columns **82** can have a maximum width **84** that is larger than the radial width **86** of the pontoon **81**. Therefore, at the point where these four columns **82** intersect the pontoon **81**, the cross-sectional area of each column **82** is greater than the corresponding area of the pontoon **81**. In this embodiment, as shown, parts of each column **82** extend radially beyond both the interior edge **81***a* and exterior edge **81***b* of the pontoon **81**.

FIG. **9** is a plan view of a C-semi **90** according to another embodiment of the present invention. As shown, the four circular cylindrical columns **97** can be coupled to the pontoon **91** at points along the perimeter of the pontoon **91** equidistant from each other.

While the pontoon **91** may be a single structure or several separate structures, for ease in description, the pontoon **91** will be referred to as having four sections or quadrants **99***a*, **99***b*, **99***c* and **99***d*; each section is coupled to two adjacent columns. The pontoon **91** is generally in the shape of a circular, hollow toroid with an interior edge **91***a* and an exterior edge **91***b*. However, each pontoon section or quadrant **99***a*, **99***b*, **99***c* and **99***d* can have linear portions **93** and non-linear portions **94**. The linear portions **93** can comprise the center of each pontoon section **99***a*, **99***b*, **99***c* and **99***d*, while the non-linear portions **94** can be nearest to the coupling points of the columns **97** and pontoon **91**. The maximum width (in this case the diameter) **98** of the columns **97** is larger than the radial width **95** of the pontoon **91**. Therefore, at the point where the column **92** intersects the pontoon **91**, the cross-sectional area of each column **92** is greater than the corresponding area of the pontoon **91**. In this embodiment, as shown, parts of each column **92** extend radially beyond the interior edge **91***a* and exterior edge **91***b*.

The pontoon sections are positioned radially outward relative to the columns. The diameter **96** from the center of the radial width of one pontoon section **93** to the center of the radial width of an opposite pontoon section **93** is preferably between 1.2 to 1.5 times the distance **95** from the center of one column **97** to the center of an adjacent column **97**. The pontoon sections are substantially longer relative to the column width **98**, and the distance **95** between central axes of adjacent columns is preferably 3.5 to 4 times the column width **98**. The preferred draft is generally between 20 to 50 meters. The draft is between 0.3 and 1 times the distance **95** from the center of one column **98** to the center of an adjacent column **98**. The draft is also typically much less than the distance **95** between central axes of adjacent columns. The pontoon width **92** varies from 0.6 to 1 times the column width **98**. The preferred pontoon height is in the range of 0.4 to 0.8 times the pontoon width **92**. The column displacement is between 0.8 to 2 times the pontoon displacement. The wave forces on the columns contribute less than the force on the pontoon for most wave periods.

FIG. **10** is a plan view of a C-semi **100** according to another embodiment of the present invention. As shown, the four square cylindrical columns **102** with round corners can be coupled to the pontoon **101** at points along the perimeter of the pontoon **101** equidistant from each other.

In this embodiment, each of the four columns can be positioned to face the center of the interior of the pontoon structure. While the pontoon **101** may be a single structure or several separate structures, for ease in description, the pontoon **101** will be referred to as having four sections or quadrants **109***a*, **109***b*, **109***c* and **109***d*; each section is coupled to two adjacent columns **102**. The pontoon **101** is generally in the shape of a circular, hollow toroid with an interior edge **101***a* and an exterior edge **101***b*. However, each pontoon section **109***a*, **109***b*, **109***c* and **109***d* can have linear portions **103** at the center and non-linear portions **104** nearest to the coupling points of the columns **102** and pontoon **101**. The maximum width **106** of the columns **102** is larger than the radial width **105** of the pontoon **101**. Therefore, at the point where the column **102** intersects the pontoon **101**, the cross-sectional area of each column **102** is greater than the corresponding area of the pontoon **101**. In this embodiment, as shown, parts of each column **102** extend radially to flush the interior edge **101***a* and exterior edge **101***b*.

FIG. **11** is an elevation perspective view of a C-semi **100** according to this embodiment of the present invention. As shown, the four square cylindrical columns **102** with round corners can be coupled to the pontoon **101** at points along the perimeter of the pontoon **101** equidistant from each other.

FIG. **12** is a plan view of a C-Semi **120** according to another embodiment of the present invention. As shown, the four circular columns **122** can be coupled to the pontoon **121** at the center of each side of the pontoon **121**. The pontoon **121** is a hollow rectangular cuboid with an interior edge **121***a* and an exterior edge **121***b*.

While the pontoon **121** may be a single structure or several separate structures, for ease in description, the pontoon **121** will be referred to as having four sections or quadrants **129***a*, **129***b*, **129***c* and **129***d*; each section is coupled to two adjacent columns **122**. The maximum width (in this case the diameter) of the columns **122** is larger than the width **125** of the pontoon **121**. Therefore, at the point where the column **122** intersects the pontoon **121**, the cross-sectional area of each column **122** is greater than the corresponding area of the pontoon **121**. In this embodiment, as shown, parts of each column **122** extend radially beyond the interior edge **121***a* and exterior edge **121***b*.

The pontoon sections are positioned radially outward relative to the columns. The diameter **126** from the center of the radial width of one pontoon section **129***a* to the center of the radial width of an opposite pontoon section **129***c* is preferably between 1.2 to 1.5 times the distance **123** from the center of one column **127** to the center of an adjacent column **127**. The pontoon sections are substantially longer relative to the column width **124**, and the distance **123** between central axes of adjacent columns is preferably 3.5 to 4 times the column width **124**. The preferred draft is generally between 20 to 50 meters. The draft is between 0.3 and 1 times the distance **123** from the center of one column **122** to the center of an adjacent column **122**. The draft is also typically much less than the distance **123** between central axes of adjacent columns. The pontoon width **125** varies from 0.6 to 1 times the column width **124**. The preferred pontoon height is in the range of 0.4 to 0.8 times the pontoon width **125**. The column displacement is between 0.8 to 2 times the pontoon displacement. The wave forces on the columns contribute less than the force on the pontoon for most wave periods.

A C-Semi with a circular cylindrical ring pontoon and straked columns is beneficial because the structure minimizes hydrodynamic and structural forces. FIG. **13** is a graph of heave response amplitude operators for a C-Semi according to the embodiment shown in FIG. **3** and a conventional semi-submersible hull at the same draft. FIG. **14** is a graph showing a detailed view around the wave peak period (Tp) in FIG. **13**. The graphs show that the C-Semi minimizes hydrodynamic loading around both the wave peak period and the natural period through cancellation and redistribution of wave excitation forces on pontoon and columns. Specifically, the

C-Semi reduces heave motions by 20% to 30% in extreme hurricane conditions when compared to a conventional semi-submersible hull at the same draft. The C-Semi reduces heave motions by 40% to 50% in fatigue sea states.

FIG. **15** is a graph of wave exciting forces on the pontoon and columns in the vertical direction corresponding to FIG. **14**. The C-Semi and conventional semi-submersible hulls have the same draft, column width, and distance between central axes of adjacent columns, and thus the same wave exciting force on columns, A. According to preferred embodiments of the present invention, the wave exciting force on the C-Semi pontoon, C, is noticeably less than the wave exciting force of the conventional semi-submersible pontoon, B, for a dominant wave peak period. Since the wave forces on the pontoon and columns act in the opposite direction, the total force on the C-Semi, C-A, is more significantly reduced than the conventional semi-submersible, B-A.

A C-Semi also minimizes vortex induced motion (VIM) by mitigating current flows through strakes. In comparison to a conventional semi-submersible hull, the C-Semi reduces VIM amplitude by 50% or more and riser fatigue damage by 80% in current sea states. The C-Semi structure also reduces VIM induced mooring and riser tension and fatigue damage. The C-Semi structure may offer additional benefits by minimizing current forces.

Furthermore, the C-Semi minimizes structural forces. In comparison to a conventional semi-submersible hull, the C-Semi reduces structural forces and stress concentrations by eliminating the sharp corners between the pontoon sections.

Thus, the preferred embodiments have been fully described above. Although the invention has been described based upon these preferred embodiments, it would be apparent to those of skill in the art that certain combinations, modifications, variations, and alternative constructions could be made to the described embodiments within the spirit and scope of the invention.

The invention claimed is:

1. An offshore floating structure for the drilling and production of oil and gas, said offshore floating structure comprising:

a generally circular toroidal, hollow pontoon of substantially a same radial width throughout a perimeter of the pontoon; and

a plurality of columns of substantially a same cross-sectional area, each coupled, at a coupling point, on a bottom end thereof to said pontoon at an equidistant point along the perimeter of said pontoon, and adapted to be coupled on a top end to a deck structure;

wherein a diameter from a center of the radial width of said pontoon is greater than a distance from a center of one said column to a center of an adjacent said column; and wherein at least one of:

said distance from the center of one said column to the center of an adjacent said column is between 3.5 to 4 times as great as the width of one of said column, or

a draft is between 0.3 to 1 times said distance from the center of one said column to the center of an adjacent said column.

2. The offshore floating structure recited in claim **1**, wherein:

said generally circular toroidal, hollow pontoon has linear and non-linear portions;

wherein said non-linear portions are nearest to said coupling points of said pontoon with said columns and said linear portions are located at a center point between said coupling points.

3. The offshore floating structure recited in claim **1**, wherein:

at said coupling points of said pontoon with said columns, the cross-sectional area of each column is greater than a corresponding area of said pontoon.

4. The offshore floating structure recited in claim **1**, wherein:

said columns extend radially beyond both interior and exterior edges of said pontoon.

5. The offshore floating structure recited in claim **1**, wherein:

said columns extend radially beyond only an interior or an exterior edge of said pontoon.

6. The offshore floating structure recited in claim **1**, wherein:

said columns are three, four, five, or six in number.

7. The offshore floating structure recited in claim **1**, wherein:

said diameter from a center of said radial width of said pontoon is 1.2 to 1.5 times said distance from a center of one said column to a center of an adjacent said column.

8. An offshore floating structure for the drilling and production of oil and gas, said offshore floating structure comprising:

a hollow, oval toroidal pontoon of substantially a same radial width throughout a perimeter of the pontoon; and

four large columns of substantially a same cross-sectional area, each coupled on a bottom end thereof to said pontoon at an equidistant point along the perimeter of said pontoon forming two non-shortest diameters, and adapted to be coupled on a top end to a deck structure; and

two small columns of substantially a same cross-sectional area, each coupled on a bottom end thereof to said pontoon at an equidistant point along the perimeter of said pontoon forming a shortest diameter, and adapted to be coupled on a top end to a deck structure.

9. The offshore floating structure recited in claim **1**, wherein:

said columns have a cross-sectional area that is circular or square with rounded corners.

10. The offshore floating structure recited in claim **1**, wherein:

said columns are provided with strakes.

* * * * *